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BOTANICAL SURVEY OF THE HURON RIVER VALLEY.

II. A PEAT BOG AND MORAINAL LAKE.[1]

LEWIS H. WELD.

(WITH SIX FIGURES)

WHILE the general history of morainal lakes and the superficial relations of their plant societies have long been familiar both to botanists and geologists, there has been great lack of detailed information regarding changes now taking place and the effects of such changes on the distribution of plants and consequent vegetable accumulations. In fact, anything approaching a satisfactory comparative study, based on reasonably complete data, has thus far been out of the question. The evidence goes to show that the rate at which morainal lakes in southern Michigan are filling up has been extremely variable and that oscillations of water level and various other changes are in progress, directly affecting biological conditions. For future critical studies, therefore, it is essential that definite observations of present conditions should be permanently recorded. The large number of morainal lakes in the Huron River Valley and the numerous peat bogs accompanying them, some of which are reported to be as much as forty feet in thickness, offer excellent opportunity for scientific exploration and commercial enterprise to cooperate with mutual advantage.

The lake, or pond, which forms the subject of the present study, is the first and smallest of the so-called Three Sister Lakes, and lies three miles west of Ann Arbor, just south of the trolley line. It is oval, or ovate, in outline, with the long axis SSW by NNE, the larger end lying towards the south. Its greatest length is 600^{ft} (180^{m}) and its width 400^{ft} (120^{m}); on the west is a strip of tamarack swamp and low ground several acres in extent, through which flows to the southwest the outlet, a mere ditch, dry except in spring. Across the road, north of the present lake, is a small marsh, part of the same basin, cut off in the early days by a corduroy road and now by the high embankment of the trolley line. It had no drainage to the north. The general relations are shown in the view from the trolley embankment (*fig. 1*).

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[1] This work, to which Mr. Weld gave a large part of his time for a year, was incomplete when he left the University of Michigan in July 1902. As the work was carefully done, it seems desirable to place his observations on record. With his approval, some necessary changes and additions have been made by V. M. Spalding, under whose direction the survey is in progress.

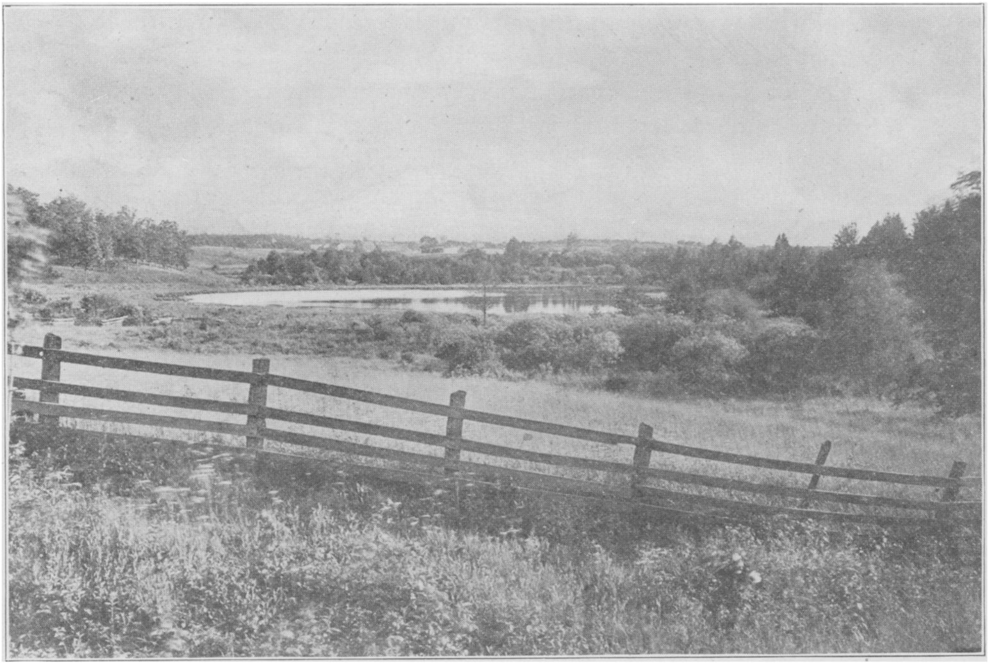

FIG. 1.—First lake from the N. W. on the trolley embankment.

About 1200^{ft} (365^{m}) to the south lies a second lake, larger and nearly circular in outline, hemmed in except on the north and northwest by badly eroded hills. Its outlet is a ditch on the north side, which joins the outlet from the first, then flows straight west, crossing the road, through a low marsh, nearly to the woods beyond, and then turns to the northwest. West of the second, a quarter of a mile away, is the third lake, the largest and deepest of the group. It is not connected with the other two, a low, gravelly ridge separating it from the marsh just east of the woods, through which the other outlet flows. The outlet of this third lake flows through a bog at its western extremity, then to the southwest, where it makes a great bend through a level plain; then, after two or three miles, it turns north again, joining the outlet of the other two and forming a branch of Honey Creek which empties into the Huron River about a mile above Foster's.

The levels of these lakes are approximately the same, *i. e.*, 914^{ft} (278^{m}) above sea level or 33^{ft} (10^{m}) above the bench-mark on the library building of the State University, and 120^{ft} (36.5^{m}) above the Huron River at the outlet of Honey Creek. The summit of the divide east of the first lake is 955^{ft} (291^{m}) above the sea, or 41^{ft} (12.5^{m}) above the lakes. The corner on Liberty Street, one mile south of Huron is 979^{ft} (298^{m}) and the kame just south of Liberty Street rises probably 75^{ft} (23^{m}) higher. It was once proposed to derive the water-supply of Ann Arbor from the third lake, pumping the water to a reservoir on top of this kame, about 140^{ft} (42^{m}) above the lake.

Ordinarily the level of the three lakes remains nearly constant throughout the year, becoming, however, 6 to 8^{in} (15–20^{cm}) higher in the spring. In the fall of 1901 the lakes were said to be lower than they had been in years. It is popularly supposed that they are fed by springs, but careful testing with a thermometer, in the fall of the year, has thus far failed to detect the influence of such springs. It is a very common thing, however, for lakes of this sort to be sub-irrigated, that is, water percolating through the stony clay of adjacent hills makes its way to the lake, and, owing to the higher water-table on all sides, maintains the level constant in the lake basin. Another thing which helps to retain the water is the fact that the bottom of the lake basin is filled with a deposit of blue clay which prevents leaching. The depth of the lakes varies with the size, the first being 18^{ft} (5.5^{m}) deep, the second over 35^{ft} (10.5^{m}), and the third 55^{ft} (16.75^{m}).

This group of lakes is of glacial origin, like numerous other small lakes of Michigan. They lie on the western slope of the terminal moraine which was formed by the Erie lobe of the ice sheet, and which now extends northeast and southwest across the county. Just south of the second and third lakes is a high kame, and these lakes lie in some of those local depressions in the drift which are characteristic of a kame area. The present outlets follow the glacial drainage channels. These flowed away from the ice front to the north and northwest to the Huron River, which at that time had just formed in the re-entrant angle between the Erie and Saginaw lobes and flowed to the west through the Portage and Grand into Lake Michigan. All the region east of this terminal moraine, including Ann Arbor, was then occupied by the ice sheet, and the glacial drainage was to the west.

As is well known, such morainal lakes are destined sooner or later to become obliterated by the combined action of erosion and vegetation. The process goes on more slowly in some than in others, depending on size, depth, character of the shores, direction of winds, and the nature of the vegetation which gets a foothold. The first lake represents a fairly advanced stage in the process, the second and third occupying a far larger proportion of their original basins.

The characteristic zonal distribution of the vegetation is well marked in all three of these basins, especially in those of the first and third, the lake lying in the center with water lilies around its margin, then sedge and sphagnum, cassandra and other shrubs, and finally forest. It is noteworthy that the lake, as in many similar cases, is nearer the eastern than the western side of its basin, the bog and forest being better developed on the western side. This is not so evident in younger stages, but is very noticeable at the first lake.

Proceeding now to a more detailed account of the vegetation of the first lake, we may conveniently follow the zones in their natural order:

1. *Potamogeton zone*.—This is represented by *Potamogeton lucens*[2] in deep water, at the outer edge of the pond lilies, not at

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[2] The nomenclature is that of Gray's Manual.

all abundant, and by *P. zosteraefolius*, which is also sparingly present. The open water is 18^{ft} (5.4^{m}) deep in the deepest place, which is near the south end. The bottom is of blue clay with a very thin film of black organic matter resting upon it. This clay bottom is derived from eroded material that has washed into the lake, chiefly before so much peat had accumulated around the borders of the basin, the finest of which, in turn, has been washed out into the middle of the lake and has settled in the deepest water. A section of the lake opposite the ice-house (*fig. 2*) shows that it is a flat-bottomed, saucer-shaped basin.

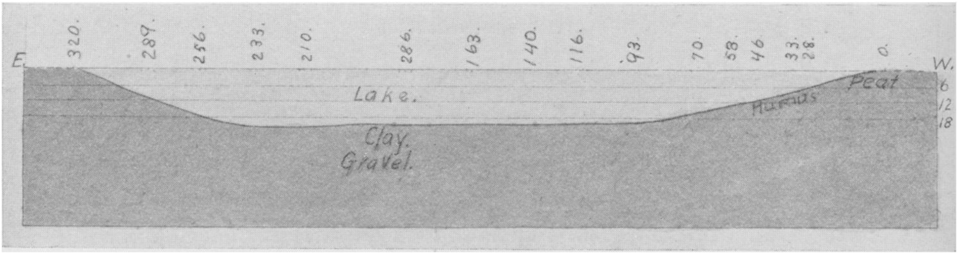

FIG. 2.—Section through lake opposite ice-house. Scale 1 : 900.

As we approach within 50 to 60^{ft} (15–18^{m}) of the shore we come to the rather steep incline of the terrace formed by the border vegetation. This is composed of dead organic material in which sphagnum is conspicuous. Even though the lake is small, the waves probably stir it to the bottom, as it is so shallow. The water is highly colored, a yellowish-brown, by the decaying organic substances, and contains much solid matter in suspension.

2. *Nuphar zone.* The terrace just described is occupied by a very prominent and almost unbroken zone of yellow pond lilies from 20 to 30^{ft} (6–9^{m}) wide, growing in water from 6^{in} to 5.5^{ft} (15–167^{cm}) deep. It is widest in the quiet water of the southwest end of the lake, while on the east there are a few short spaces where it is interrupted altogether; but on the whole it is an almost perfect zone. These lilies are most efficient agents in reclaiming a lake. Not only can they creep out with their stout rootstocks into 6^{ft} (2^{m}) or more of water, binding together

the humus and contributing to it by their own decay, but their long petioles and large leaves break the force of the waves so that in the quiet water thus afforded a variety of less resistant forms can grow, adding the products of their decomposition to that of the lilies and to the débris which they collect.

The plants found growing here in the lily zone are :

Nuphar advena, giving character to the zone and preferring shallower and more quiet water than the next; Nymphaea odorata, in two isolated patches only, as if recently introduced; Brasenia peltata, replacing the lilies in two places; Potamogeton natans, a few specimens; Ceratophyllum demersum, scattering, not in dense beds; Utricularia sp., close to shore not abundant; Chara sp., two flourishing clumps near shore, each about a foot square, apparently recently introduced; Naias flexilis.

This zone then is made up almost wholly of Nuphar, which is replaced in spots by Nymphaea or Brasenia, while a very small number of other plants, represented by few individuals, grow on the soft, black, almost bare bottom. It would seem, therefore, that the yellow pond lily is an agent of prime importance in forming the soil in which various plants named in the following sections flourish. The relative importance of species in this and succeeding zones in the formation of peat should be investigated.

3. *Carex and sphagnum zone.* This is separated from the lily zone by a distinct though irregular line of demarcation. It presents a low, level appearance, being formed in great part of grasses and sedges uninterrupted by taller plants or shrubs (*fig. 3*). Its flora, however, is varied, consisting of about thirty species. Carex, with some six species, predominates; and, with several grasses, ferns, and other plants, forms a thick, tough, flexible mat resting on water or liquid mud beneath. This zone is less distinctly defined and the mat less compact, and hence less safe to walk upon, on the eastern than on the western side. Ordinarily, however, it will hold a man's weight clear to the edge, even when the water is high in the spring, without breaking. Some species of plants prefer the lakeward border, growing at or near the water's edge; among these are the sensitive and flowering ferns, swamp milkweed, Dulichium, Eleocharis, and certain other sedges, besides seedlings of Bidens and a mint, evi-

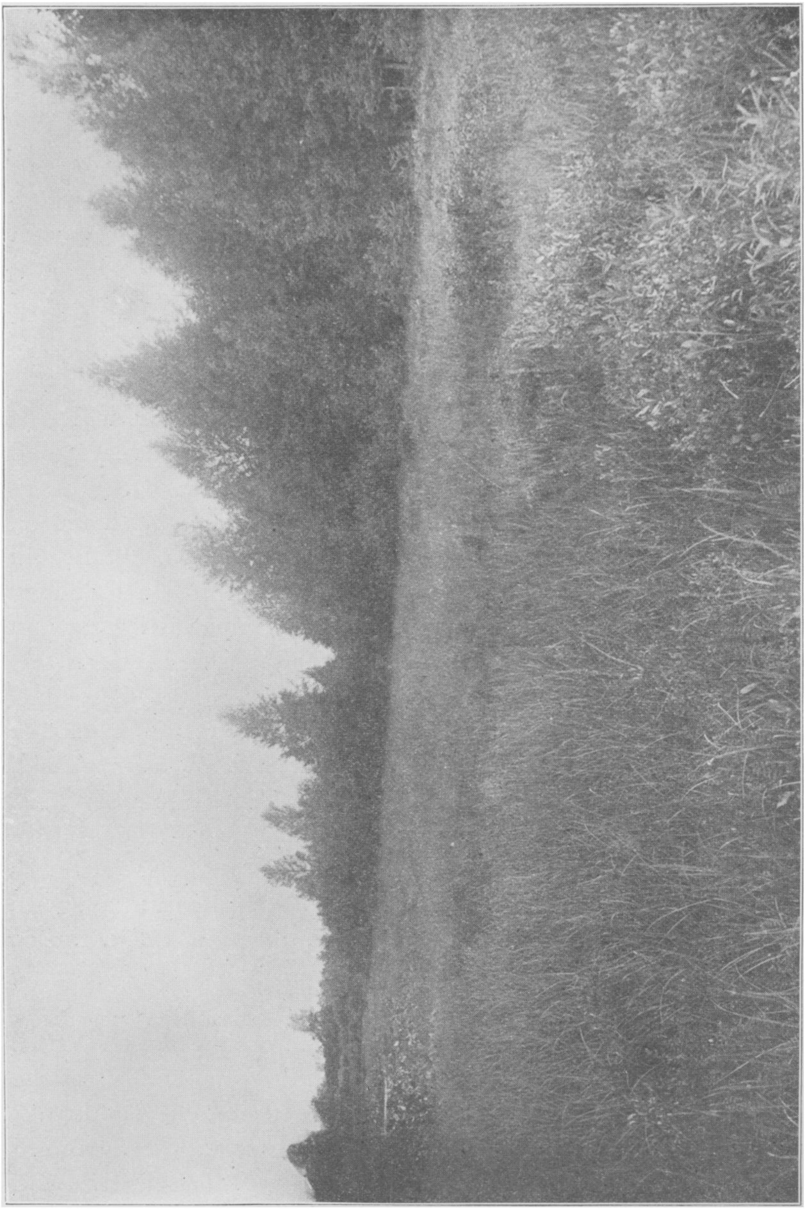

FIG. 3.—Zone of sedges. Taken at south end of lake, looking S. W.

dently from seeds that have floated to the places where they are growing. Others grow further back, among which are the cranberry, buck-bean, white violet, and sphagnum. Following is a list of the plants of this zone, as far as determined, somewhat in the order of their relative importance and abundance.

Carex filiformis, Glyceria nervata, Eleocharis palustris, Aspidium noveboracense, Viola blanda, Menyanthes trifoliata, Potentilla palustris, Equisetum limosum, on east side near edge of water, Vaccinium Oxycoccus on S. E. and N. W., Carex four species, Onoclea sensibilis, Osmunda regalis, Asclepias incarnata, Dulichium spathaceum, Eupatorium perfoliatum, Mentha canadensis, many seedlings of Bidens and Impatiens in spring, Cassandra calyculata, Salix myrtilloides, Eriophorum gracile, Scutellaria galericulata, Campanula aparinoides.

At the north end of the lake, in a particularly soft place, is a patch of *Typha latifolia*, but elsewhere there is a sharp transition between lilies and sedges, the Pontederia and Typha zones as commonly represented being wanting at this lake.

4. *Cassandra zone.* This zone is characterized by an advance of shrubs, of which cassandra is the most conspicuous. This, with the accompanying sphagnum, is active in raising the marsh and preparing it for tree growth (*fig. 4*). It is not present in all cases, but when present the succeeding forest floor is much drier. Its development here is weak. It is accompanied by Andromeda, chokeberry, small willows, huckleberry, low birch, and mountain holly. Around some lakes east of Whitmore this zone of shrubs is much better developed, consisting, however, of willows as dominant species, with no cassandra.

The plants of this zone at the first lake include: Cassandra calyculata, Sphagnum sp., Andromeda polifolia, Pyrus arbutifolia melanocarpa, Nemopanthes fascicularis, Gaylussacia resinosa, Salix myrtilloides, Viola blanda, Rumex Acetosella in the drier spots, Lycopus lucidus americanus, Glyceria nervata, Aspidium noveboracense, Osmunda cinnamomea, Solidago sp., Sarracenia purpurea growing half hidden in the sphagnum at the base of the clumps of cassandra, Drosera rotundifolia between clumps of cassandra with sphagnum and buck-bean at the northwest side of the lake, Arethusa bulbosa growing in the sphagnum, Habenaria lacera, Pogonia ophioglossoides, Calopogon pulchellus, Menyanthes trifoliata.

We are still at a loss to explain the distribution of these bog plants, particularly the orchids.

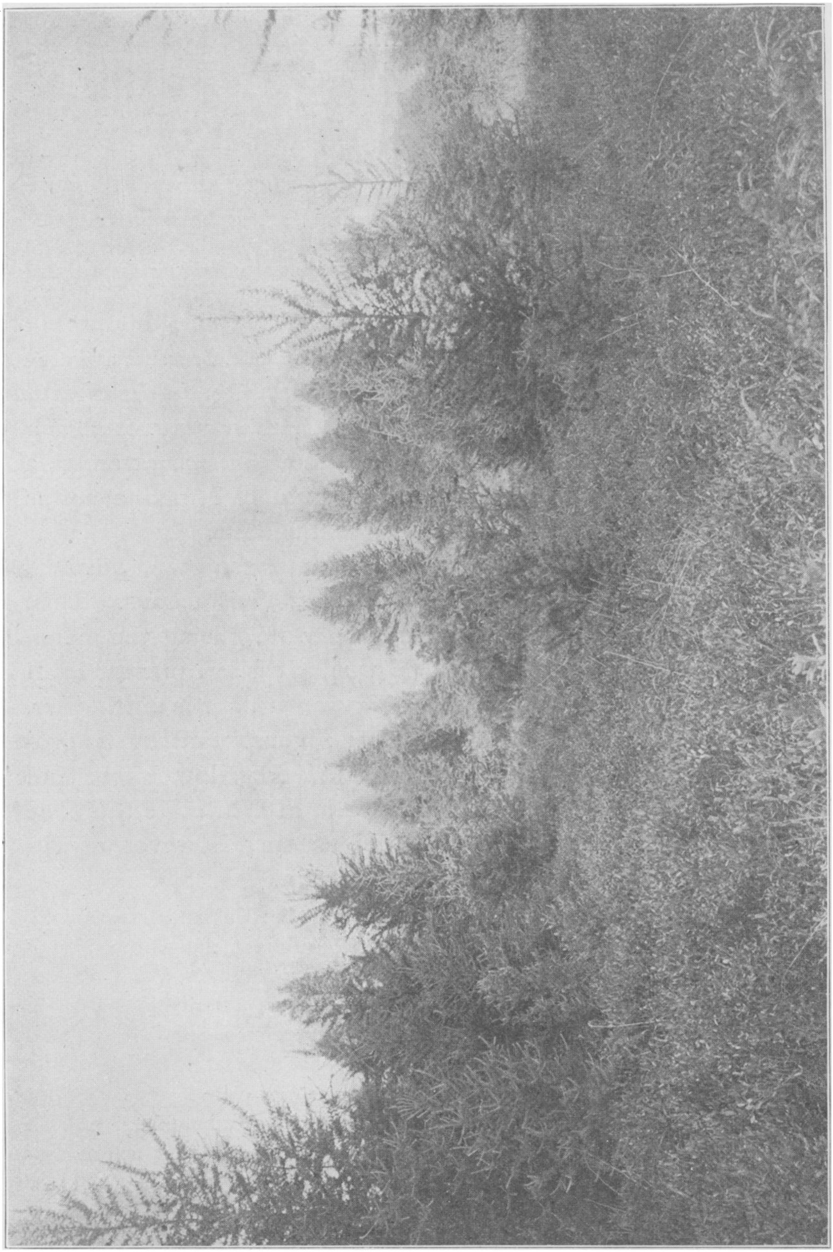

FIG. 4.—Young tamaracks; cassandra underneath.

5. *Forest.* Next comes the only tree that seems to be able to endure these conditions, the tamaracks, small ones advancing into the cassandra zone, in one instance even within 6^{ft} (1.8^{m}) of the water and farther back larger trees $12–16^{in}$ ($30–40^{cm}$) in diameter (*fig. 4*). This forms a forest of one species of tree, constituting the grove west of the lake. There the trees stand close together, and the shrub vegetation, cassandra in particular, is killed by lack of light. The forest floor is covered with dead brown needles, with only the occasional green of a moss, sedge, fern, or composite pushing through between the clumps of dead cassandra. This is one type of bottom vegetation in a pure tamarack woods. Where the growth of tamaracks is more open, particularly if the ground is rather wet, a great variety of leafy herbaceous undergrowth completely covers the ground. This is the case in a swamp near Cavenaugh Lake, where under the scattered tamaracks there is a rank growth of skunk cabbage, indian turnip, ferns, woodbine, grape, vervain, mints, elder, and juniper. In this case cassandra had not been present in the basin to dry the bottom. Another swamp near Whitmore, consisting of small trees close together, was found to be very wet, the roots of the trees creeping on top of the ground and densely covered with sphagnum, little else being present. No cassandra had been there.

Into the pure tamarack forest at the first Sister Lake, where the conditions permit, namely in the grove on the northwest, the following are now coming in :

Prunus serotina, Acer dasycarpum, Populus tremuloides, Rhus glabra, Quercus rubra, Rubus villosus, Osmunda cinnamomea, O. regalis, Pteris aquilina.

Leaving the basin level and the forest and going up hill on the west side, we pass to ground that has been cultivated, now in meadow. A few feet up the hillside we come to a distinct zone of white vervain, about 10^{ft} (3^{m}) wide, which winds around the foot of the hill, its position evidently determined by water supply.

The succession of plant societies as here described, which is ideally perfect on the north and northwest, has been modified elsewhere by conditions induced by human agency. Thus the area east of the lake, beyond the line fence, is characterized by an absence of forest and a scanty development of shrubs, though tamaracks once stood there within the memory of old settlers, and the stumps are still present. After they were cut, continued pasturing prevented their coming in again and favored the development of sod. West of the fence, however, where stock has been excluded, there is a good development of both trees and shrubs, and no sod has been formed. South of the ditch to the west of the lake the tamaracks were cut off, perhaps fifteen years ago, and cassandra and other shrubs have come in, with a multitude of young tamaracks which will eventually kill out the cassandra. A portion of this area, where the tamaracks were cut, was burned over in or near 1890. Following the burning, a dense growth of Marchantia covered the ground, but it has all disappeared since, and the ground is now occupied by

Populus tremuloides, Populus grandidentata, Salix rostrata, S. lucida, S. amygdaloides, S. cordata × sericea?, Pyrus arbutifolia melanocarpa, Acer dasycarpum, Cornus stolonifera, Larix americana, Rubus villosus, R. strigosus, Rhus glabra, Pteris aquilina, Osmunda cinnamomea, O. regalis, Poa pratensis, Eupatorium perfoliatum, Typha latifolia, and other species, constituting a swamp clearing society. Occupation by a much wider range of species is possible and often occurs.[3]

The general topography and the extent of the vegetable deposits show at a glance that this lake was once much larger and its level some higher than at present. By digging a series of holes in the basin through the peat the bottom contour of the old lake is seen to conform to the present contour of the surrounding hills. It is thus found that the old lake included the marsh north of the road, for a boring in the road near the sluice shows 2^{ft} (61^{cm}) of till, washed in and brought in to build the road, and below that 7^{ft} (2.1^{m}) of peat. A series of borings 100^{ft} (30^{m}) apart (*fig. 5*) shows that to the east of the line fence the lake was comparatively shallow, shown by the 8 to 9^{ft} (2.4–2.7^{m}) of peat, with a gently sloping bank on the eastern side, as would be expected from the contour of the present hill.

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[3] The above lists were made in spring, and accordingly include few composites. The attempt has been made to give representative lists rather than complete ones.

West of the fence, however, the peat is over 20 ft (6 m) thick, and here was a deep part of the lake. In a few of these borings an attempt was made to determine the thickness of the blue clay, but there is no sharp separation between the clay and the gravel beneath. *Figure 6* shows a cross section of the basin in an east and west line through the north end of the lake. The western slope was not so steep at this place and the lake was more disk-shaped. How much deeper than 20 ft the peat may be in places near the lake has not been ascertained.

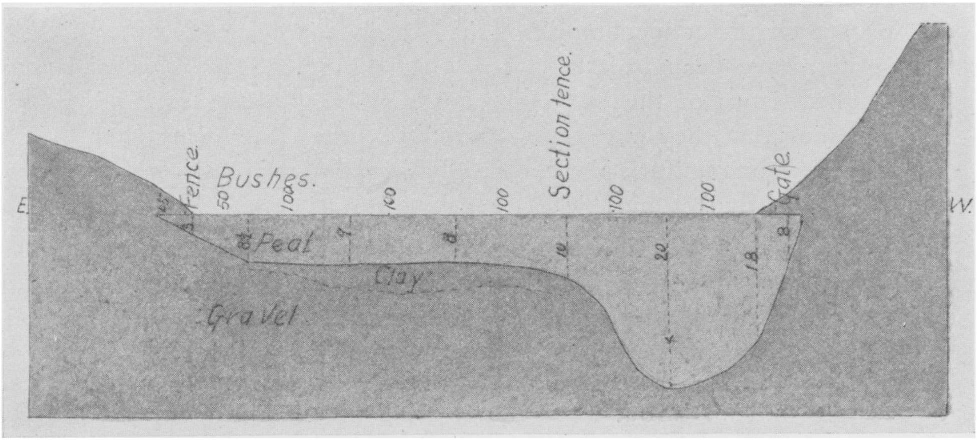

FIG. 5.—Section across lake basin from E. to W., halfway between lake and road, in line with fence. Hor. scale 1 : 2160; vert. scale 1 : 360.

Directly south of the lake is a shallow valley leading over to the second lake. A boring in the bottom of this at the fence shows 8 ft (2.4 m) of gravelly clay mixed with dark organic materials. This valley was once quite deep and formed a connection between the lakes, but being narrow was filled up by erosion rather than by vegetable deposits. West of this valley is a hill now under cultivation, and to the west of this is a broad valley in which runs the present outlet of both lakes. The peat in this valley is over 16 ft (5 m) deep, showing that here was a broad and deep connection with the second lake, the hill being at that time an island.

The Three Sisters were then originally two lakes, the third, which has always been separate, and one from which the first and second and the marsh north of the road have been derived. The original lakes were some 5 to 6^ft^ (1.5–1.8^m^) higher than at present, as is shown by a beach or terrace north of the second lake, and by other evidence. Their lowering is apparently due in great part to better drainage since open ditches have been cut in the outlet channels.

It is very desirable that a complete enumeration and comparison of the fauna and flora of the first and second lakes should be made. Here are two lakes that once were one, but except for the connection through a ditch running only in the spring, have been isolated for a long period. The physical characteristics of the two lakes are now very different, and, assuming that they were both inhabited by the same forms when there was one uniform condition, it would be reasonable nevertheless to expect modifications or variations to arise, particularly in the aquatic life, following the changes in external conditions. Some differences in the present plant life of the two lakes are now very noticeable, the phytoplankton of the first being very different from that of the second. The latter contains an enormous number of blue-green algae, Oscillaria and others, or at least did all through the winter and spring, while the first lake had none. Desmids appeared in great abundance in a culture dish from the first lake, while the other gave few. More diatoms have been present in the second lake than in the first. The second contains many Volvox, not found at all in the first, and some Eudorina. Two representatives of the Peridineae, *Peridinium tabulatum* Ehrh. and *Ceratium hirudinella* O. F. Müller, occur in each lake. The paucity of higher plants is noticeable. The first lake has no Elodea or Myriophyllum, only three species of Potamogeton, little Ceratophyllum, and but two small clumps of Chara. The flora of the second lake, not yet sufficiently studied, is apparently quite as scanty. The presence or absence of flowering plants seems to be largely a matter of the chances of dispersal, but this certainly does not account for the differences in the phytoplankton of the two lakes. In seeking an explanation of this account must be made of their physical differences, among which the following are to be specially considered:

1. *Color.* The water of the second lake is clear, or would be if the blue-green algae were filtered out, while that of the first is highly colored, a yellowish-brown, due to the great amount of decomposed vegetable substances about the lake. This latter fact is the greatest difference between the two lakes, perhaps the cause of all others, but there is as yet no wholly satisfactory explanation of the antecedent fact that something like 95 per cent. of the work of filling one basin has already been done, while the process is but fairly started in the other. The greater depth of the second may have something to do with this. The ice in the first lake is clear as crystal. Freezing in winter and evaporation in summer serves to concentrate the amount of dissolved salts in the water and thus still further deepen the color.

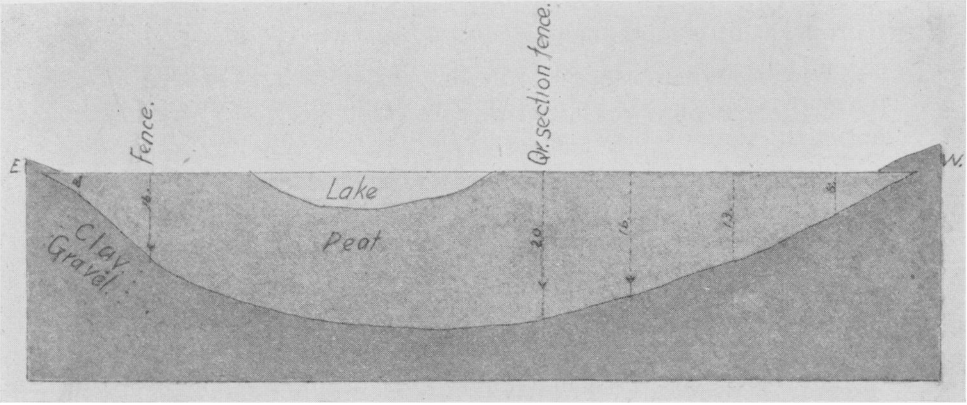

FIG. 6.—Section across lake basin from E. to W. at ditch. Scale as in *fig. 5*.

2. *Turbidity.* Absorption of light, as is well known, is much greater in colored than in clear water, and it is also occasioned by turbidity due to the presence of solid matter in suspension. Turbidity is most conveniently measured in the field by the wire method of Hazen, which consists in observing the depth at which a platinum wire 1^{mm} in diameter disappears when lowered horizontally into the water. The scale is furnished by the recip-

rocal of the depth in inches at which the wire becomes invisible. As recently modified by Whipple and Jackson, turbidities are read directly from the scale as parts by weight of suspended matter in a million of water, making this a very simple observation and worthy the attention of botanists engaged in the study of aquatics. November 12, 1902, a reading of 11.5 was obtained. No readings were taken on the second lake.

3. *Temperature.* This, coupled with depth, may account for periodic phenomena observable particularly in the case of diatoms. The first lake is so shallow that stagnation never occurs. The bottom is a little more than a degree cooler than the surface. The second lake is over 35^{ft} (10.6^{m}) deep in places, and, though no temperature readings have yet been taken, stagnation may occur, causing at the time of the spring and fall overturning an increase in the diatom flora. At all events the second lake showed many limnetic diatoms in the spring, more than in May, leading to the inference that stagnation does occur.

The chemical composition of the water, which may be the determining factor for the presence of blue-green algae in one lake and their absence from the other, has not yet been examined.

The facts here presented show plainly that the history of these morainal lakes, as regards their vegetation, is by no means identical. Differences of depth and contour, of soil and drainage, of water supply and the chances of seed dispersal, with other less conspicuous factors, have resulted in great differences in the rate of filling up and in the character of their plant life. The first lake stands as a representative of a large number in this valley that show essentially the same succession of plant societies. After the retreat of the ice the ground could hardly have been left bare for any considerable period. If this had been the case, the evidence would be seen in much greater erosion than has actually taken place. As it is, these areas, held by vegetation, show the even curves of ice- and water-formed topography. We are to think of forest-covered hills surrounding a newly formed lake basin. Aquatics and amphibious plants are already growing about its edge, and as the humus accumulates, sedges, bushes, and finally trees follow. As the basin becomes filled up with peat the lake first disappears from the center, then the bog, and so on until a tamarack woods fills the basin. Into this pure growth of tamarack there come in slowly elm, ash, maple, birch, basswood, and their accompanying undergrowth. A swamp near Cavenaugh Lake was observed where elms and ash a foot and a half in diameter had come in, overtopped the tamaracks, and killed them. This swamp had a very leafy undergrowth. Thus the final stage is a damp, rich-woods flora of soft woods; never does a hard-wood flora take possession, as far as my observations in this region extend, although an occasional oak or juniper may be found.

The history just outlined has been greatly modified in individual cases, as the remarkable differences between the first and second lakes plainly show, and future investigations should take full account of such differences. Thus far, critical comparisons of the flora of different lakes and bogs and the conditions affecting their plant life are wanting. The distribution of their phytoplankton presents many unexplained facts, and the factors determining the peculiarities of bog xerophytes are still an unsolved riddle. The deposition of peat is progressing with varying rapidity in numerous bogs and swamps in southern Michigan, but the processes involved in its formation and affecting not merely its fuel value but its fitness for further plant growth, and hence the composition of succeeding plant societies, are still very imperfectly known. The valley of the Huron River, with its great number of lakes and variety of conditions, offers a favorable area for more extended study of these problems.

SUMMARY.

1. These lakes were formed in the moraine at the front of the ice sheet when the Erie lobe extended 3 miles (5^{km}) west of Ann Arbor. The present outlets follow the glacial drainage to the west into the Huron River, which then flowed west into Lake Michigan.

2. The third lake never was connected with the others. The first and second were once one, with an island in the center. Subsequent lowering of water and filling of channels has made two lakes.

3. Since their separation the physical characters of the two lakes have become very different, leading to marked differences in the character of their plankton.

4. These differences appear to be due primarily to the greater depth of the second and the more rapid filling of the basin of the first lake. The reasons for the latter are not clear.

5. A luxuriant flora probably flourished on the terminal moraine at the time of retreat of the ice sheet. The lake was first invaded by aquatic and amphibious plants. As humus accumulated, there followed in turn sedges and sphagnum, shrubs, a pure tamarack, and then a mixed, soft-wood, deciduous forest.

6. Vegetation accumulated faster on the western than on the eastern side of the lake, due at least in part to the direction of prevailing winds. The ax, fire, and pasturage have obscured the order of succession in some places and prolonged the period required for the ultimate reclamation of the basin. Other causes, not yet sufficiently investigated, have resulted in marked differences in composition of the bog floras of this and neighboring lakes, and in the constitution and rapidity of formation of the vegetable substances with which they are becoming filled.

University of Michigan.